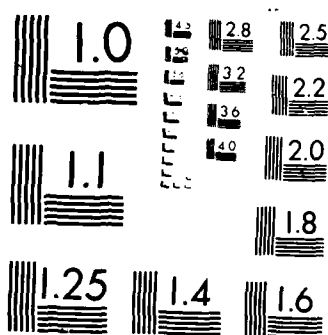


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RELIABILITY MODELING AND INFERENCE FOR COHERENT SYSTEMS 1/1  
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INTERCOLLEGE DIV OF STATISTICS F J SAMANIEGO 01 JUL 84  
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ROCOPY RESOLUTION TEST CHART

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## ANNUAL REPORT

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July 1, 1984 - June 30, 1985

F.J. Samaniego, Principal Investigator

Our efforts during this period were largely devoted to the study of three specific problems: (1) The estimation of the lifetime distribution of a system subject to imperfect repair. (2) The estimation of a life distribution known to belong to the class of distributions for which "new is better than used in expectation" and (3) Multivariate modeling of the joint distribution of component lifetimes for systems under repair. Results are discussed below.

Our study of statistical inference for repairable systems focuses on the development of estimation procedures for the life distribution  $F$  of a new system, based on data on system lifetimes between consecutive repairs. The Brown-Proschan 'Imperfect Repair' model postulates that, at failure, the system is repaired to a condition as good as new with probability  $p$  and is otherwise repaired to the condition just prior to failure. In treating issues of statistical inference for this model, we begin by noting the lack of identifiability of the pair  $(p, F)$  as an index of the distribution of interfailure times  $T_1, T_2, \dots$ . We show that data pairs  $(T_i, Z_i)$ ,  $i=1, 2, \dots$  are necessary to render the parameter pair  $(p, F)$  identifiable, where  $Z_i$  is a Bernoulli variable which records the mode of repair (perfect or imperfect) following the  $i^{\text{th}}$  failure. We demonstrate that the nonparametric maximum likelihood estimator of  $F$  exists only in special cases, but that a neighborhood maximum likelihood estimator  $\hat{F}$  (using the language of Kiefer

and Wolfowitz) always exists and may be derived in closed form. We demonstrate the strong uniform consistency of  $\hat{F}$  under mild assumptions, and prove weak convergence of  $\hat{F}$  to a Gaussian process. These results are shown to extend to various experimental designs (including renewal testing and inverse sampling) and to various generalizations of the Brown-Proschan model (including the age-dependent imperfect repair model of Block, Borges and Savits).

A distribution function is said to be "New Better than Used in Expectation" (NBUE) if for all  $t > 0$ , the expected residual life length of a used item of age  $t$  is no larger than the expected life length of a new item. We address the problem of constructing a consistent estimator of  $F$  which also belongs to the NBUE class. A minimum distance estimator is obtained as a solution to a nonlinear programming problem. We develop a numerical algorithm for finding this solution, and establish the strong uniform consistency of the estimator.

For the development of optimal repair-and-maintenance policies for multi-component systems, a family of joint survival functions has been generated from a realistic model for the aging process; these functions can be described briefly as being exponential in a quadratic function of the variables. Using maximum expected failure-free duration as the optimality criterion, it is shown that intermediate level of repair can be optimal, depending on the parameters of the system.

Results have been obtained on two additional problems: (i) Parametric modeling and inference for random records and (ii) general modeling of the multivariate lack of memory property. Technical reports on the five problems mentioned have been submitted under separate cover.



Goals for future research include the development of: (1) methods of statistical inference based on data from more complex models for imperfect repair (2) inference techniques for the reliability of complex networks and (3) optimal maintenance policies for specific multi-component systems.

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